

OPTICAL FIBER COMPONENT FOR SPOT SIZE
TRANSITION AND METHOD OF MAKING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an optical fiber component for spot size transition and a method of making the same. In particular, the present invention relates to an optical fiber component for spot size transition constituted by splicing optical fibers with different core diameters and a method of making the same.

Description of the Related Art

An optical fiber communication network has been established rapidly in accordance with development of a communication network in recent years. The optical fiber communication network is basically constituted by splicing an outdoor optical fiber cable and an indoor apparatus or the like. In a situation in which demands for a communication network are increasing, high density packaging of optical fibers is inevitable. For example, in intra-machine wiring or the like, since the number of optical fibers increases inevitably, saving of a space for containing the optical fibers and wiring of the optical fibers are major matters of concern.

In order to contain and wire a large number of optical fibers in a limited space, it is necessary to bend the optical

fibers with a small radius of curvature. However, if the optical fibers are bent with a small radius of curvature, light easily leaks and a quality of a communication network as a whole is degraded.

Thus, in order to prevent light from easily leaking even if the optical fibers are bent with a small radius of curvature, a so-called high Δ optical fiber has started to be used, in which a refractive index difference between a core and a clad, that is, a relative refractive index difference Δ , is larger than that of a single mode (SM) fiber which is a conventional optical fiber used in a communication network. A relative refractive index difference Δ of the high Δ optical fiber is 0.5 to 2.5%, whereas a refractive index difference Δ of the SM fiber is about 0.3%. If a relative refractive index difference is increased in this way, since a core diameter decreases, a spot size also decreases. Here, the spot size is a parameter indicating spread of electromagnetic field distribution, that is, field distribution of a propagation mode in an optical waveguide, and is also called a mode field diameter.

However, such a high Δ optical fiber is also eventually required to be spliced with the ordinary optical fiber which constitutes the optical fiber cable. As a result, a large transition loss is caused because mismatching occurs in a spliced portion due to not only a difference of core diameters but also a difference of spot sizes. For example, when the SM fiber

and a high Δ optical fiber with a spot size, which is about half of that of the ordinary optical fiber, are spliced in an abutting state using a connector or the like, a large transition loss of about 2 dB occurs due to a difference of spot sizes.

In order to eliminate such mismatching in a spliced portion of a SM fiber and a high Δ optical fiber, there are known the following two techniques. One is a technique for, after fusion-splicing the SM fiber and the high Δ optical fiber, heating the high Δ optical fiber to thereby thermally diffuse a dopant in the fibers to expand a core diameter such that an optimal spot size is obtained. The other is a technique for heating the high Δ optical fiber to thereby thermally diffusing a dopant in the fiber and expand a core diameter such that an optimal spot size is obtained and, then, cutting the part of the expanded core diameter to fusion-splice the high Δ optical fiber with the SM fiber (e.g., see Japanese Patent No. 2618500).

In addition, there is also known a technique for cutting the expanded part and mounting the high Δ optical fiber to an optical connector such that a cut face thereof becomes an light incident and outgoing end face (e.g., see Japanese Patent No. 2619130).

Incidentally, the above-mentioned conventional techniques have problems to be solve as described below.

Japanese Patent No. 2618500 and Japanese Patent No. 2619130 describe a technique for expanding the core diameter

of the high Δ optical fiber and, then, cutting the expanded part to splice the high Δ optical fiber with the SM fiber. However, in the case in which a cutting portion is decided such that an optimal spot size is obtained, since a transition loss is confirmed after splicing the high Δ optical fiber and the SM fiber, it is difficult at the time of cutting to judge whether the cutting portion is always a portion where the optimal spot size is obtained. Thus, a highly accurate cutting technique and experiences are required.

In addition, in the case in which a core diameter is expanded by heating an optical fiber, the expanded core diameter may fluctuate depending upon heating conditions, and it is impossible to cut a large number of optical fibers always in an identical portion when core diameters of the optical fibers are expanded. Thus, it is difficult to steadily optimizes spot sizes of the large number of optical fibers.

Moreover, in the case in which the high Δ optical fiber is mounted to the optical connector with the core expanded portion as the incident and outgoing end face, since an advanced technique is required for grinding the incident and outgoing end face in order to obtain an optimal spot size, it is difficult to increase working efficiency. Thus, process management becomes complicated.

SUMMARY OF THE INVENTION

The present invention provides an optical fiber component, in which spot sizes of optical fibers with different core diameters are optimized steadily, and a method of making the same.

In order to solve the above-mentioned problems, the present invention has constitutions as described below.

First, a first invention is an optical fiber component for changing spot sizes of optical fibers with different core diameters, the optical fiber component for spot size transition having arranged therein: a large-diameter core optical fiber having a light incident and outgoing end face; a spliced portion in which the large-diameter core optical fiber and a small-diameter core optical fiber are fusion-spliced; a spot size transition portion in which a core diameter of the small-diameter core optical fiber is expanded in the vicinity of the spliced portion; and the small-diameter core optical fiber.

In addition, a refractive index profile in the spot size transition portion continuously changes in the longitudinal direction of the optical fiber, and the spot sizes of the large-diameter core optical fiber and the small-diameter core optical fiber match in the spliced portion.

Further, a relative refractive index difference in the spliced portion of the spot size transition portion is substantially identical with a relative refractive index

difference of the large-diameter core optical fiber.

Moreover, the optical fiber component has the large-diameter core optical fiber, the spliced portion, the spot size transition portion, and the small-diameter core optical fiber co-arranged inside a ferrule.

Next, a second invention is a method of making an optical fiber component for changing spot sizes of optical fibers with different core diameters, the method of making an optical fiber component for spot size transition comprising: fusion-splicing a large-diameter core optical fiber and a small-diameter core optical fiber to form a spliced portion, heating the vicinity of the spliced portion and thermally diffusing a dopant contained in the small-diameter core optical fiber to thereby expand the core diameter for forming a spot size transition portion, and then cutting an arbitrary position of the large-diameter core optical fiber to set the cut face as a light incident and outgoing end face, and arranging the large-diameter core optical fiber, the spliced portion, the spot size transition portion, and the small-diameter core optical fiber inside the optical fiber component.

In addition, in the case in which the dopant is heated and thermally diffused to expand the core diameter of the small-diameter core optical fiber and form the spot size transition portion, a refractive index profile in the spot size transition portion is continuously changed in the longitudinal

direction of the optical fiber, and the vicinity of the spliced portion is heated until spot sizes of the large-diameter core optical fiber and the small-diameter core optical fiber match in the spliced portion.

Further, in the case in which the dopant is heated and thermally diffused to expand the core diameter of the small-diameter core optical fiber and form the spot size transition portion, heating is performed until a relative refractive index difference of the spot size transition portion becomes substantially identical with a relative refractive index difference of the large-diameter core optical fiber in the spliced portion.

Moreover, in the case in which the dopant is thermally diffused to expand the core diameter of the small-diameter core optical fiber and form the spot size transition portion, heating is performed while a transition loss of the spliced portion is monitored.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a diagram showing an embodiment of the present invention;

Figs. 2A to 2C are diagrams showing an embodiment of a method of making an optical fiber component of the present invention; and

Fig. 3 is a diagram showing a transition loss of an optical fiber component of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will be hereinafter described using a specific example.

Fig. 1 is a longitudinal sectional view of an optical fiber component for spot size transition of the present invention. In Fig. 1, a large-diameter core optical fiber 1 comprises a core 1a and a clad 1b. The core 1a is doped with Ge which is a dopant for increasing a refractive index, and the clad is pure quartz. This optical fiber 1 is the same as a single mode fiber used for an ordinary communication network, and a relative refractive index difference thereof is 0.3%.

On the other hand, a small-diameter core high Δ optical fiber 2 comprises a core 2a and a clad 2b. The core 2a is also doped with Ge, and the clad is also pure quartz. A doping amount of Ge doped in the core 2a is larger than a doping amount of Ge doped in the core 1a of the optical fiber 1. Thus, the high Δ optical fiber 2 is an optical fiber highly resistant against bending. The high Δ optical fiber 2 is also a single mode fiber, and a relative refractive index difference thereof is 0.5 to 2.5%. A degree of the relative refractive index difference of the high Δ optical fiber 2 depends upon a place where it is implemented. Thus, it is sufficient to select a most suitable

relative refractive index difference according to a laying environment thereof.

The optical fiber 1 and the high Δ optical fiber 2 are fusion-spliced in a spliced portion 3. Then, a core diameter of the high Δ optical fiber 2 in the vicinity of this spliced portion 3 is expanded to form a spot size transition portion 4. The spot size transition portion 4 is a portion in which the vicinity of the spliced portion 3 is heated to diffuse Ge doped in the core 2a of the high Δ optical fiber 2 into the clad 2b to expand the core diameter of the core 2a. A refractive index profile continuously changes in the longitudinal direction of the high Δ optical fiber 2 in the spot size transition portion 4. In addition, relative refractive index differences of the optical fiber 1 and the high Δ optical fiber 2 are substantially identical in the spliced portion 3. With such a constitution, increase in a transition loss due to mismatching of spot sizes between the optical fiber 1 and the high Δ optical fiber 2 is eliminated.

Further, both the spliced portion 3 and the spot size transition portion 4 are arranged so as to be located inside a ferrule 5. On a light incident and outgoing side in the ferrule 5, the large-diameter core optical fiber 1 is arranged and a light incident and outgoing end face 6 is formed. Since the optical fiber 1 has a relative refractive index difference identical with that of an optical fiber used in the ordinary

communication network, increase in a transition loss is never caused even if, for example, the optical fiber 1 is spliced with the optical fiber used in a communication network in the part of the light incident and outgoing end face 6.

Here, in this embodiment, the optical fiber with Ge, which is a dopant for increasing a refractive index, doped in the core is described as an example. However, the dopant is not limited to Ge, and other dopants may be adopted. In addition, for example, the same constitution can be adopted in an optical fiber with F, which is a dopant for decreasing a refractive index, doped in a clad.

Next, a method of making an optical fiber component for spot size transition of the present invention will be described. Figs. 2A to 2C are diagrams for explaining a process of the method of making an optical fiber component for spot size transition of the present invention. Note that portions identical with those described in Fig. 1 will be denoted by the identical reference numerals. In Fig. 2A, the optical fiber 1 is a single mode fiber used in an ordinary communication network with a relative refractive index difference of 0.3%, in which the core 1a is doped with Ge and the clad 1b is a pure quartz. In addition, the high Δ optical fiber 2 is also a single mode fiber with a relative refractive index difference of 0.5 to 2.5%, in which the core 2a is doped with Ge and the clad 2b is a pure quartz. The optical fiber 1 and the high Δ optical

fiber 2 are fusion-spliced with end faces thereof abutted against with each other.

Note that external diameters of the optical fiber 1 and the high Δ optical fiber 2 may be identical or may be different. In this embodiment, the splice of optical fibers with an identical external diameter is described. However, for example, one of the optical fibers may be a conventional optical fiber with an external diameter of 125 μm and the other may be S-Tylus (registered trademark of Showa Electric Wire & Cable Co., Ltd.) in which an optical fiber with an external diameter of 115 μm is covered with non-releasable resin.

When the optical fiber 1 and the high Δ optical fiber 2 are fusion-spliced, the external diameters thereof are identical in the spliced portion 3. However, the core diameters thereof are different from each other. Actually, the core diameter $2a$ of the high Δ optical fiber 2 is slightly expanded by heat at the time of fusion-splicing, which is insufficient for the object of the present invention. A length L of a spot side transition portion required for the present invention is 1 to 2 mm when, for example, a ratio γ of a core diameter of a large-diameter core optical fiber and a core diameter of a small-diameter core optical fiber is assumed to be 2 (e.g., in the case in which the diameters are 10 μm and 5 μm , respectively).

In Fig. 2 after fusion-splicing the optical fiber 1 and

the high Δ optical fiber 2, the vicinity of the spliced portion 3 is heated by heating means 7 such as a burner, a heater, or electric discharge. An area to be heated is about several millimeters. However, it is sufficient to decide conditions such as a heating range, a heating time, and a heating temperature appropriately according to a size of a core diameter to be expanded. At this point, it is preferable to continuously change a refractive index profile in the spot size transition portion 4 in the longitudinal direction of the high Δ optical fiber 2, and heat the spliced portion 3 until spot sizes of the optical fiber 1 and the high Δ optical fiber 2 match in the spliced portion 3. In addition, it is advisable to expand the core 2a of the high Δ optical fiber 2 until relative refractive index differences of the optical fiber 1 and the high Δ optical fiber 2 become substantially identical to form the spot size transition portion 4. In order to make the spot sizes of the optical fiber 1 and the high Δ optical fiber 2 match or the relative refractive index differences of the optical fiber 1 and the high Δ optical fiber 2 substantially identical; it is advisable to always monitor a transition loss of the spliced portion 3 during heating and stop the heating at the point when the transition loss of the spliced portion 3 is minimized. Note that in the case of the above-mentioned S-Tylus, since an external diameter thereof is smaller than that of the conventional optical fiber, thermal conductivity is increased,

an expansion effect of a core diameter is improved, and working efficiency is improved.

Then, as shown in Fig. 2C, an arbitrary position of the optical fiber 1 is cut by a cutting blade 8 to form a light incident and outgoing end face 6. It is sufficient to cut the optical fiber 1 in a part of an appropriate length such that both the spliced portion 3 and the spot size transition portion 4 are placed in a ferrule. Thereafter, all of the optical fiber 1, the spliced portion 3, the spot size transition portion 4, and the high Δ optical fiber 2 are arranged inside the ferrule 5 shown in Fig. 1, and then the light incident and outgoing end face 6 is grinded to constitute the optical fiber component of the present invention. This optical fiber component is mounted to, for example, a not-shown optical connector and used for connector-splicing or the like of an ordinary optical fiber and a high Δ optical fiber.

Fig. 3 shows a result of measuring a transition loss of the spliced portion 3. The result indicates a loss at the time when a transition loss is monitored during heating of the spliced portion 3 in expanding a core diameter, and the heating is stopped at the point when the transition loss becomes the lowest. A heating temperature is 1400 °C, and a heating time is several minutes to several tens minutes, although the heating time fluctuates slightly because it is a time until the transition loss becomes the lowest. According to Fig. 3, an average value

of the transition loss is 0.025 dB, and a maximum value thereof is 0.06 dB, which are extremely low compared with a transition loss due to mismatching of spot sizes in the past.

In other words, the present invention attempts to solve the problems in that, when a core diameter of a high Δ optical fiber is expanded, and then the expanded portion is cut to fusion-splice or connector-splice the high Δ optical fiber with a SM-fiber used in a communication network, a portion where the expanded portion of the core diameter is cut is not stabilized, a transition loss fluctuates, and a highly accurate cutting technique or grinding technique is required. For this purpose, first, the ordinary optical fiber and the high Δ optical fiber with different core diameters are fusion-spliced, then the core diameter of the small-diameter core high Δ optical fiber is expanded to form an appropriate spot size transition portion, and then an arbitrary position of the large-diameter core optical fiber is cut to constitute an optical fiber component. The large-diameter core optical fiber used in the optical fiber component of the present invention has a core diameter identical with that of the optical fiber used in a communication network, and this core diameter is uniform in the longitudinal direction. Thus, an advanced technique is not required for deciding a cutting portion. In addition, the large-diameter core optical fiber is arranged on a light incident and outgoing end face side. Thus, since optical fibers of the same type as the optical

fiber used in a communication network are spliced, for example, even in the case in which the SM optical fiber and the high Δ optical fiber are spliced by an optical connector or the like, increase in a transition loss can be suppressed, and an optical fiber component with stable characteristics is obtained.

According to the optical fiber component for spot size transition and the method of making the same of the present invention as described above, an optical fiber component having an appropriate spot size transition portion can be manufactured without requiring an advanced technique. In addition, an optical fiber component, which does not cause increase in a transition loss even in the case in which a high Δ optical fiber is spliced with a SM optical fiber used in a communication network, can be provided.